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(54) Title: PROCESS FOR MULTI-LAYER COATING OF SUBSTRATES

(57) Abstract: The invention relates to a process for multi-layer coating of substrates, in particular vehicles and vehicle parts, by applying two or more coating layers and curing of the applied coatings, wherein at least one of the coating layers is produced from a coating composition which comprises a binder system with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxysilane groups, wherein the resin solids content of the coating composition exhibits an equivalent weight of C=C double bonds of 200 - 2000, preferably of 300 - 1500, and a content of silicon bound in alkoxysilane groups of 1 - 10 wt.-%, preferably of 1 - 7 wt.-%, especially preferably of 2 - 6 wt.-%, and wherein curing of the coating layer, of which there is at least one, proceeds by free-radical polymerisation of the C=C double bonds on irradiation with high energy radiation and by the formation of siloxane bridges under the action of moisture.

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## **TITLE OF INVENTION**

### **Process for Multi-Layer Coating of Substrates**

#### **Field of the Invention**

The invention relates to a process for the multi-layer coating of substrates, in particular vehicles and vehicle parts, wherein curing of at least one of the layers of the multi-layer structure, preferably the outer layer, is performed with high energy radiation and by means of moisture.

#### **Description of Related Art**

Various dual cure systems are known in coatings technology which combine curing by means of high energy radiation, in particular by means of UV radiation, with moisture curing. Such systems generally comprise organopolysiloxane binders which contain both hydrolysable silane groups and free-radically polymerizable, olefinically unsaturated groups. WO 99/67318, for example, describes a binder system based on two differently functionalized polysiloxanes, wherein one polysiloxane comprises (meth)acryloyl groups and the second polysiloxane comprises ethylenically unsaturated groups and hydrolysable silane groups. This binder system is used in potting applications and in coating compositions for electronic components and electronic circuits.

JP 5311082 describes a radiation- and moisture-curing binder system which is produced by reacting a polyether comprising amino end groups or a polybutadiene/acrylonitrile copolymer with compounds which contain epoxy and alkoxysilane groups and further reacting the resultant reaction product with compounds which contain (meth)acryloyl groups and, for example, NCO groups. One-layer coatings are obtained which are tack-free after 24 hours and exhibit good tear strength and elongation.

WO 94/09013 discloses a UV-curable coating system with good electrical properties for electronic circuits, which system additionally cures by means of moisture. A urea oligomer with acryloyl groups and alkoxysilane groups is used, which oligomer is produced, for example, from a urea derivative, in particular the reaction product of a diisocyanate and an amine containing alkoxysilane groups and a (meth)acryloyl-functional diol.

It is also known to use coating compositions curable by means of UV radiation in vehicle coating. Coating compositions based on free-radically polymerizable binders are in particular used in such applications. One shortcoming of these UV-curable coatings is, inter alia, that, when three-dimensional objects are to be coated, only inadequate curing is observed in shaded areas, i.e., in areas that are not reached or only inadequately reached by the UV radiation. In an attempt to remedy this problem, "dual cure" systems, i.e., binder systems, that cure both by free-radical polymerization with UV-irradiation and by another cross-linking mechanism, for example, by means of an OH/NCO reaction. Examples of such dual cure systems are described in WO-A-98/00456 and DE-A-197 09 560. Binder systems which cure not only by UV curing but additionally by an OH/NCO reaction are two-component systems, which must be prepared in two components and can be mixed together only shortly before application.

Nothing is known from the prior art concerning the use of coating compositions that are curable both by means of UV radiation and by means of moisture for the multi-layer coating of vehicles and parts thereof.

There is a requirement when coating vehicles and vehicle parts for multi-layer coating processes using coating compositions curable by means of UV radiation, in particular coating compositions for producing the outer layer of a multi-layer coating, with which processes coatings are obtained which have elevated hardness and scratch resistance and good chemical resistance and with which elevated cross-linking is achieved even in shaded areas not reached by the UV radiation. In particular, adequate hardness, scratch resistance and good chemical resistance should also be achieved even at low curing temperatures of, for example, no more than 80°C, within relatively short curing times.

### **Summary of the Invention**

The invention relates to a process for the multi-layer coating of substrates, in particular vehicles and vehicle parts, by the application of two or more coating layers and curing of the applied coatings, wherein at least one of the coating layers is produced from a coating composition which comprises a binder system with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxy silane groups, wherein the resin solids content of the coating composition exhibits an

equivalent weight of C=C double bonds of 200 - 2000 , preferably of 300 - 1500, and a content of silicon bound in alkoxysilane groups of 1 - 10 wt-%, preferably of 1 - 7 wt-%, especially preferably of 2 - 6 wt-%, and wherein curing of the coating layer, of which there is at least one, proceeds by free-radical polymerization of the C=C double bonds on irradiation with high energy radiation and by the formation of siloxane bridges under the action of moisture.

The invention preferably relates to a process for the multi-layer coating of substrates, in particular vehicles and vehicle parts, by applying two or more coating layers and curing of the applied coatings, wherein the outer layer of the multi-layer structure is prepared from a coating composition which comprises a binder system with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxysilane groups, wherein the resin solids content of the coating composition exhibits an equivalent weight of C=C double bonds of 200 - 2000 , preferably of 300 - 1500, and a content of silicon bound in alkoxysilane groups of 1 - 10 wt-%, preferably of 1 - 7 wt-%, especially preferably of 2 - 6 wt-%, and wherein curing of the coating layer, of which there is at least one, proceeds by free-radical polymerization on irradiation with high energy radiation and by the formation of siloxane bridges under the action of moisture.

### **Detailed Description of the Embodiments**

The resin solids content of the coating compositions curable by means of high energy radiation and by means of moisture includes the binder system with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxysilane groups, together with any optionally present reactive diluents.

The outer layer of the multi-layer structure may comprise a clear coat layer applied onto a color-imparting and/or special effect-imparting base coat layer or a pigmented one-layer top coat layer applied onto a prior coating. It may also comprise a transparent sealing layer which is applied, for example, onto the outer coating layer of a multi-layer coating, in particular onto a clear coat layer or a pigmented one-layer top coat layer, in order to achieve particular scratch resistance.

It has surprisingly been found that it is possible by means of the process according to the invention to produce clear coat layers or one-layer top coat layers

and sealing layers which, in addition to adequate hardness, also exhibit elevated cross-linking and chemical resistance in shaded areas, wherein these properties can be achieved even at low curing temperatures of, for example, no more than 80°C, within relatively short curing times.

The coating compositions curable by means of high energy radiation and by means of moisture used in the process according to the invention contain binders with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxy silane groups. The free-radically polymerizable olefinic double bonds and the hydrolysable alkoxy silane groups may here in principle be present in the same binder and/or in separate binders.

The coating compositions used in the process according to the invention cure by means of two different cross-linking mechanisms. Cross-linking proceeds, on the one hand, by means of free-radical polymerization of olefinic double bonds and, on the other, by means of the hydrolysis and subsequent condensation of alkoxy silane groups to form siloxane bridges.

Suitable binders with free-radically polymerizable olefinic double bonds which may be considered are, for example, any binders known to the skilled person which can be cross-linked by free-radical polymerization. These binders are prepolymers, such as, polymers and oligomers, containing, per molecule, one or more, for example, on average 1 to 20, preferably 2-10, particularly preferably 2-6 free-radically polymerizable olefinic double bonds.

The polymerizable double bonds may, for example, be present in the form of (meth)acryloyl, vinyl, allyl, maleate and/or fumarate groups. (Meth)acryloyl groups are preferred.

Both here and below, (meth)acryloyl and (meth)acrylic are respectively intended to mean acryloyl and/or methacryloyl and acrylic and/or methacrylic.

Examples of prepolymers or oligomers include (meth)acryloyl-functional poly(meth)acrylates, polyurethane (meth)acrylates, polyester (meth)acrylates, unsaturated polyesters, polyether (meth)acrylates, silicone (meth)acrylates, epoxy

(meth)acrylates, amino (meth)acrylates and melamine (meth)acrylates. The number

average molar mass  $M_n$  of these compounds may, for example, be from 500 to 10000 g/mol, preferably from 500 to 5000 g/mol. The binders may be used individually or as a mixture.

Compounds which contain free-radically polymerizable double bonds in the form of the preferred (meth)acryloyl groups may be produced in accordance with conventional methods. This may proceed, for example, by: transesterifying OH-functional resins, such as OH-functional polyesters, polyacrylates, polyurethanes, polyethers or epoxy resins, with alkyl esters of (meth)acrylic acid; esterifying the stated OH-functional resins with (meth)acrylic acid; reacting the stated OH-functional resins with isocyanate-functional (meth)acrylates; reacting acid-functional resins, such as polyesters, polyacrylates, polyurethanes with epoxy-functional (meth)acrylates; reacting epoxy-functional resins, such as polyesters, polyacrylates, epoxy resins with (meth)acrylic acid. These production methods stated by way of example are described in the literature and known to the person skilled in the art.

The (meth)acryloyl-functional prepolymers may be used in combination with reactive diluents, i.e., free-radically polymerizable low molecular weight compounds with a molar mass of below 500 g/mol. The reactive diluents may be mono-, di- or polyunsaturated. Examples of monounsaturated reactive diluents are (meth)acrylic acid and the esters thereof, maleic acid and the semi-esters thereof, vinyl acetate, vinyl ether, substituted vinyl ureas, styrene, vinyltoluene. Examples of diunsaturated reactive diluents are di(meth)acrylates such as alkylene glycol di(meth)acrylate, polyethylene glycol di(meth)acrylate, 1,3-butanediol di(meth)acrylate, vinyl (meth)acrylate, allyl (meth)acrylate, divinylbenzene, dipropylene glycol di(meth)acrylate, hexanediol di(meth)acrylate. Examples of polyunsaturated reactive diluents are glycerol tri(meth)acrylate, trimethylolpropane tri(meth)acrylate, pentaerythritol tri(meth)acrylate, pentaerythritol tetra(meth)acrylate. The reactive diluents may be used alone or in mixture.

Binders with hydrolysable alkoxysilane groups which may be considered are those conventional binders known to the person skilled in the art which may be functionalized with alkoxysilane groups. The alkoxysilane groups may comprise monoalkoxysilane, dialkoxysilane and/or trialkoxysilane groups. Trialkoxysilane

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groups are preferred. The alkoxysilane groups comprise, for example, 1-10, preferably, 1-3 C atoms in the alkoxy residue.

The binders bearing alkoxysilane groups may be produced, for example, by: copolymerizing alkoxysilane-functional (meth)acrylate monomers or by copolymerizing vinylalkoxysilanes; reacting OH-functional resins, such as, OH-functional polyesters, polyacrylates, polyurethanes, polyethers or epoxy resins with isocyanate-functional alkoxysilanes; reacting epoxy-functional resins with aminoalkoxysilanes; reacting acid-functional resins with epoxy-functional alkoxysilanes; reacting isocyanate-functional resins (for example, polyurethanes, polyesterurethane prepolymers, polyetherurethane prepolymers, acrylate copolymers with free NCO groups) with aminoalkoxysilanes; reacting isocyanate-functional resins with OH-functional alkoxysilanes produced in situ, for example, by addition of aminoalkoxysilanes onto cyclic carbonates. The particular reaction must be performed with exclusion of water in order to suppress premature hydrolysis of the alkoxysilane groups.

Binders bearing both olefinic double bonds, in particular (meth)acryloyl groups, and hydrolysable alkoxysilane groups which may be considered are those conventional binders known to the person skilled in the art which may be functionalized with (meth)acryloyl groups and alkoxysilane groups. These resins may, for example, be produced as follows:

(Meth)acryloyl groups, such as those described above, are first incorporated into an appropriate resin. Residual OH groups may then be reacted with isocyanate-functional alkoxysilanes or residual epoxy groups may be reacted with aminoalkoxysilanes or some of the acryloyl groups may be reacted with aminoalkoxysilanes.

The equivalent ratio of free-radically polymerizable olefinic double bonds to hydrolysable alkoxysilane groups (mono-, di- and trialkoxysilane groups are in each case calculated as one equivalent) in the binder system may be, for example, 1:0.1 to 1:5, preferably 1:0.2 to 1:4.

The binders with free-radically polymerizable olefinic double bonds and/or

hydrolysable alkoxysilane groups may furthermore additionally contain hydroxyl groups. The hydroxyl groups may be obtained or introduced using measures known to the person skilled in the art. For example, the hydroxyl groups may be introduced by reacting NCO groups still present in the binders with polyols. The additionally present hydroxyl groups have a catalytic action on moisture curing and can also react with the alkoxysilane groups under a condensation reaction.

Free-radical inhibitors may be added to the binders in order to prevent premature polymerization of the double bonds present. Examples of free-radical inhibitors are hydroquinone, 4-methoxyphenol, 2,6-di-tert.-butyl-4-methylphenol, phenothiazine, 3,5-di-tert.-butyl-4-hydroxyanisole, 2-tert.-butyl-4-hydroxyanisole, 3-tert.-butyl-4-hydroxyanisole, p-benzoquinone.

The coating compositions curable by means of high energy radiation and by means of moisture which are usable in the process according to the invention are liquid coating compositions. The liquid coating compositions may contain organic solvents.

The organic solvents optionally present in the liquid coating compositions comprise conventional coating solvents.

The coating compositions may contain photoinitiators in order to initiate free-radical polymerization. Suitable photoinitiators include, for example, those which absorb in the wavelength range from 190 to 600 nm. Examples of photoinitiators for free-radically curing systems are benzoin and derivatives, acetophenone and derivatives, such as, for example, 2,2-diacetoxyacetophenone, benzophenone and derivatives, thioxanthone and derivatives, anthraquinone, 1-benzoylcyclohexanol, organophosphorus compounds, such as for example acyl phosphine oxides. The photoinitiators are used, for example, in quantities of 0.1-7 wt-%, preferably of 0.5-5 wt-%, relative to the total of free-radically polymerisable prepolymers, reactive diluents and photoinitiators. The photoinitiators may be used individually or in combination. They may also be used in combination with suitable coinitiators, for example amines, such as tertiary amines.



The coating compositions may contain catalysts to catalyse moisture curing.

Examples of such catalysts are Lewis bases, for example, cycloaliphatic amines, such as, diazabicyclooctane, diazabicycloundecene, and diazabicyclononene; aliphatic amines, such as, triethylamine, tripropylamine, diethanolamine, monoethanolamine, triethanolamine, diethylethanolamine, dimethylethanolamine, dipropylethanolamine, and dimethylisopropanolamine. Further examples of catalysts are organo tin compounds, such as, dibutyltin dilaurate, dibutyltin dioctoate and acid catalysts, such as, for example, formic acid, p-toluenesulfonic acid, dodecylbenzenesulfonic acid, dinonylnaphthalenedi- or -monosulfonic acid. The catalysts may be blocked, for example, blocked p-toluenesulfonic acid, dodecylbenzenesulfonic acid, dinonylnaphthalenedisulfonic acid or dinonylnaphthalenemonosulfonic acid. The catalysts may be used individually or in combination with one another.

The coating compositions curable by means of high energy radiation and by means of moisture which are usable in the process according to the invention may comprise pigmented or unpigmented coating compositions for producing any desired layer of a multi-layer structure. Preferably, however, they comprise, as already described above, transparent clear coats, transparent sealing coats or pigmented one-layer top coats.

The coating compositions curable by means of high energy radiation and by means of moisture used in the process according to the invention may contain transparent as well as color-imparting and/or special effect-imparting pigments and extenders. Suitable color-imparting pigments are any conventional coating pigments of an organic or inorganic nature. Examples of inorganic or organic color-imparting pigments are titanium dioxide, micronised titanium dioxide, iron oxide pigments, carbon black, azo pigments, phthalocyanine pigments, quinacridone or pyrrolopyrrole pigments. Examples of special effect-imparting pigments are metal pigments, for example, made from aluminum, copper or other metals; interference pigments, such as, for example, metal oxide coated metal pigments, for example, titanium dioxide coated or mixed oxide coated aluminum, coated mica, such as, for example, titanium dioxide coated mica and graphite effect pigments. Soluble dyes may also be present. Examples of usable extenders are silicon dioxide, aluminum silicate, barium sulfate, calcium carbonate and talcum.

In addition to the already stated initiators, inhibitors and catalysts, the coating composition may contain further conventional coating additives. Examples of further conventional coating additives are levelling agents, rheological agents, such as, highly disperse silica or polymeric urea compounds, thickeners, for example, based on partially cross-linked, carboxy-functional polymers or on polyurethanes, defoamers, wetting agents, anticratering agents, degassing agents, thermolabile initiators, antioxidants and light stabilizers based on HALS (hindered amine light stabilizers) products and/or UV absorbers. The additives are used in conventional amounts known to the person skilled in the art.

The coating compositions may be formulated as single-component or two-component coating compositions, depending upon whether a blocked or unblocked catalyst is used for moisture curing. If an unblocked catalyst is used, the binders curable by means of high energy radiation and by means of moisture, i.e., at least the binders with the hydrolysable alkoxysilane groups, are present in one component and the unblocked catalyst is present in a second component. If a blocked catalyst is used, the coating compositions may be provided as a single-component formulation without any need to prepare a second component.

According to a first preferred embodiment, the coating composition based on a binder system curable by means of high energy radiation and by means of moisture that is used in the process according to the invention is a clear coating composition that is applied onto a pigmented base coat layer of a waterborne or solvent borne base coat to produce a clear coat layer.

According to a second preferred embodiment, the coating composition based on a binder system curable by means of high energy radiation and by means of moisture that is used in the process according to the invention is a one-layer top coat composition that is applied onto a substrate coated with one or more coating layers, for example, with a primer and/or surfacer layer, to produce a pigmented top coat layer.

According to a third preferred embodiment, the coating composition based on a binder system curable by means of high energy radiation and by means of moisture

is used in the process according to the invention to produce an outer transparent sealing layer.

In the process according to the invention, the coating compositions may be applied using known methods, preferably by means of spraying.

Substrates which may be used are the various materials used in vehicle construction, for example, metals, such as, iron, zinc, aluminum, magnesium, stainless steel or the alloys thereof or plastics, such as, polyurethanes, polycarbonates or polyolefins.

When applying the coating compositions based on a binder system curable by means of high energy radiation and by means of moisture, it is, for example, possible to proceed in such a manner that the corresponding coating composition is initially applied onto the particular substrate, wherein application may be followed by flashing-off, for example, within a period of 5 to 40 minutes, at 20 to 60°C. After the optional intermediate flash-off phase, irradiation with high energy radiation can proceed. UV radiation or electron beam radiation may be used as high energy radiation. UV radiation is preferred. Irradiation may proceed continuously or discontinuously (in cycles).

Irradiation may be carried out, for example, in a belt unit fitted with one or more UV radiation emitters or with one or more UV radiation emitters positioned in front of the object to be irradiated, or the area to be irradiated, or the substrate to be coated and/or the UV radiation emitter(s) is(are) moved relative to one another during irradiation. For example, the subject to be coated may be moved through an irradiation tunnel fitted with one or more UV radiation emitters, and/or a robot equipped with one or more UV radiation emitters may guide the UV radiation emitter(s) over the substrate surface.

In principle, the duration of irradiation, distance from the object and/or radiation output of the UV radiation emitter may be varied during UV irradiation. The preferred source of radiation comprises UV radiation sources emitting in the wave length range from 180 to 420 nm, in particular, from 200 to 400 nm. Examples of such UV radiation sources are optionally doped high, medium and low pressure

mercury vapour emitters and gas discharge tubes, such as, for example, low pressure xenon lamps. Apart from these continuously operating UV radiation sources, however, it is also possible to use discontinuous UV radiation sources. These are preferably so-called high-energy flash devices (UV flash lamps for short). The UV flash lamps may contain a plurality of flash tubes, for example, quartz tubes filled with inert gas, such as, xenon. The UV flash lamps have an illuminance of, for example, at least 10 megalux, preferably, from 10 to 80 megalux per flash discharge. The energy per flash discharge may be, for example, 1 to 10 kJoule.

The irradiation time with UV radiation when UV flash lamps are used as the UV radiation source may be, for example, in the range from 1 millisecond to 400 seconds, preferably, from 4 to 160 seconds, depending on the number of flash discharges selected. The flashes may be triggered, for example, about every 4 seconds. Curing may take place, for example, by means of 1 to 40 successive flash discharges.

If continuous UV radiation sources are used, the irradiation time may be, for example, in the range from a few seconds to about 5 minutes, preferably less than 5 minutes.

The distance between the UV radiation sources and the substrate surface to be irradiated may be, for example, 5 to 60 cm.

Irradiation with UV radiation may proceed in one or more successive irradiation steps. In other words, the energy to be applied by irradiation may be supplied completely in a single irradiation step or in portions in two or more irradiation steps.

Curing under the reaction of moisture is carried out by exposure to conditions of sufficient moisture, e.g., by exposure to humidity.

In order to promote rapid development of satisfactory hardness, scratch resistance, chemical resistance and resistance to resin of trees in the shaded areas too, it is advantageous to expose the applied coating layer to thermal energy before, during and/or after UV irradiation. The coating layer may, for example, be exposed to temperatures of approximately 60°C to 160°C, preferably, 80°C to 120°C (object

temperature in each case). It is, however, particularly advantageous in order to achieve good resistance values and adequate tack-free drying and hardness also in the shaded zones for curing to proceed even at temperatures of no more than 80°C in short curing times of, for example, 10 to 30 minutes.

The process according to the invention may be used in industrial and vehicle coating, in particular in vehicle original coating and in vehicle repair coating.

The following Examples are intended to illustrate the invention in greater detail. The following abbreviations have been used: pbw means parts by weight, and wt-% means weight percent.

### Examples

#### Example 1

##### Production of alkoxy silane-functional urethane acrylates A)

478 pbw of hexamethylene diisocyanate biuret (75%, Tolonate® HDB/75 from Rhodia), 8 pbw of neopentyl glycol and 30 pbw of butyl acetate were initially introduced into a 2 liter, four-necked flask fitted with a stirrer, thermometer and column. The reaction mixture was heated to a maximum of 60°C. 235 pbw of a secondary aminoalkoxysilane (Silquest® A 1170, Witco) were then apportioned in such a manner that the temperature did not exceed 80°C. Rinsing was performed with 40 pbw of butyl acetate. Once an NCO value of < 5.9 had been reached, 0.6 pbw of methylhydroquinone and 0.5 pbw of dibutyltin dilaurate solution (10%) were added. 149 pbw of butanediol monoacrylate were then apportioned in such a manner that the temperature did not exceed 80°C. The reaction mixture was stirred and the temperature was not allowed to exceed a maximum of 80°C until an NCO value was no longer detectable. The mixture was then diluted with 60 pbw of butyl acetate.

A colorless resin solution was obtained with a solids content of 72.3% (1h/150°C), a viscosity of 1840 mPas (Höppler, 25°C), a calculated double bond equivalent weight of 725 and a calculated content of silicon bound in alkoxy silane groups of 5,1 wt-%, relative to resin solids content.

#### Example 2

529 pbw of hexamethylene diisocyanate biuret (75%, Tolonate® HDB/75 from Rhodia), 9 pbw of neopentyl glycol and 20 pbw of butyl acetate were initially introduced into a 2 litre, four-necked flask fitted with a stirrer, thermometer and column. The reaction mixture was heated to a maximum of 60°C. 179 pbw of a secondary amino alkoxysilane (Dynasilan 1189, Degussa) were then apportioned in such a manner that the temperature did not exceed 80°C. Rinsing was performed with 40 pbw of butyl acetate. Once a NCO value of < 6.3 % had been reached, 0.6 pbw of methylhydroquinone and 0.5 pbw of dibutyltin dilaurate solution (10%) were added. 165 pbw of butanediol monoacrylate were then apportioned in such a manner that the temperature did not exceed 80°C. The reaction mixture was stirred and the temperature was not allowed to exceed a maximum of 80°C until an NCO value was no longer detectable. The mixture was then diluted with 57 pbw of butyl acetate.

A colorless resin solution was obtained with a solids content of 73.2% (1h/150°C), a viscosity of 2660 mPas (Höppler, 25°C), a calculated double bond equivalent weight of 655 and a calculated content of silicon bound in alkoxysilane groups of 2,8 wt-%, relative to resin solids content.

### Example 3

#### Production of alkoxysilane-functional urethane acrylates C)

121 pbw of a primary aminoalkoxysilane (Dynasilan AMMO, Degussa) were reacted with 86 pbw of butyl acrylate in 35 pbw of butyl acetate in a 2 litre, four-necked flask fitted with a stirrer, thermometer and column. Once the exothermic reaction had subsided, 515 pbw of hexamethylene diisocyanate biuret (75%, Tolonate® HDB/75 from Rhodia) and 35 pbw of butyl acetate were added. At a maximum temperature of 80°C, the reaction was continued until an NCO value of 7.15% was reached. The reaction mixture was then combined with 0.6 pbw of methylhydroquinone and 0.5 pbw of dibutyltin dilaurate (as 10% solution). 156 pbw of hydroxyethyl acrylate were then apportioned in such a manner that the temperature did not exceed 80°C. The reaction mixture was stirred and not allowed to exceed a maximum of 80°C until an NCO value was no longer detectable. The mixture was then diluted with 51 pbw of butyl acetate.

A colorless resin solution was obtained with a solids content of 70.0% (1h/150°C), a viscosity of 1065 mPas (Höppler, 25°C), a calculated double bond equivalent weight of 558 and a calculated content of silicon bound in alkoxysilane groups of 2,5 wt-%, relative to resin solids content.

#### Example 4

##### Production of clear coats

Clear coats 1-3 usable in the process according to the invention were formulated from the following constituents:

##### Clear coat 1 (single-component):

70.0 wt-% of urethane acrylate resin A from Example 1  
0.6 wt-% of Tinuvin® 400/85 (UV absorber; CIBA)  
0.5 wt-% of Tinuvin® 292 (HALS; CIBA)  
0.3 wt-% of Byk 341/52 (levelling agent; Byk)  
0.9 wt-% of Darocur® 1173 (photoinitiator; CIBA)  
0.3 wt-% of Irgacure® 819 (photoinitiator; CIBA)  
2.0 wt-% of Nacure® 2500 (p-toluenesulfonic acid based catalyst, blocked; King Industries)  
25.4 wt-% of Solvesso® 100 (mixture of aromatic hydrocarbons)

##### Clear coat 2 (single-component):

70.0 wt-% of urethane acrylate resin B from Example 2  
0.6 wt-% of Tinuvin® 400/85 (UV absorber; CIBA)  
0.5 wt-% of Tinuvin® 292 (HALS; CIBA)  
0.2 wt-% of Tego Rad 2100 (levelling agent; Tego Chemie Service GmbH)  
0.9 wt-% of Darocur® 1173 (photoinitiator; CIBA)  
0.3 wt-% of Irgacure® 819 (photoinitiator; CIBA)  
0.5 wt-% of DBTL (dibutyltin dilaurate; catalyst)  
27.0 wt-% of Solvesso® 100 (mixture of aromatic hydrocarbons)

Component 1:

70.0 wt-% of urethane acrylate resin C from Example 3

0.5 wt-% Sanduvor® 3058 (HALS; CIBA)

0.5 wt-% of Sanduvor® 3206 (UV absorber; CIBA)

0.3 wt-% of Tego Rad 2100 (levelling agent; Tego Chemie Service GmbH)

0.9 wt-% of Darocur® 1173 (photoinitiator; CIBA)

0.3 wt-% of Irgacure® 819 (photoinitiator; CIBA)

27.6 wt-% of Solvesso® 100 (mixture of aromatic hydrocarbons)

Component 2 (catalyst):

90.0 wt-% of xylene

10.0 wt-% of p-toluenesulfonic acid

100 pbw of component 1 were mixed shortly before application with 5 pbw of component 2.

Clear coats 1-3 produced above were adjusted to spraying viscosity (24 seconds, flow cup 4) with Solvesso® 100.

Application and curing of clear coats 1-3

The clear coats 1-3 produced above were applied to a dry film thickness of approximately 35 µm onto steel sheets coated with conventional commercial electro-dipcoating, surfacer and base coat (flashed off). After flashing off for 10 minutes at room temperature and drying within 20 minutes at 80°C (circulating air oven), each of the coatings was irradiated with a conventional commercial UV-radiation emitter (medium pressure mercury emitter from Fusion, 240 W/cm, 100% output, at a UV-emitter/object distance of 5.5 cm and a belt speed of 3 m/min).

In order to simulate curing in the shaded areas of an appropriately shaped three-dimensional substrate, i.e., in the areas of a substrate which are not reached by the UV radiation emitters, metal test sheets were produced in a manner similar to that described above and coatings 1-3 were then cured only with moisture/thermal



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energy. After application, the coatings were in each case left for 10 minutes at room temperature (flash-off phase) and then cured for 20 minutes at 80°C (circulating air oven).

The following table shows the technical properties of the resultant coatings.

	Coating 1 thermal only	Coating 1 thermal + UV	Coating 2 thermal only	Coating 2 thermal + UV	Coating 3 thermal only	Coating 3 thermal + UV
Indentation (mm)	7.5	6.5	8.0	7.0	7.5	6.5
Scratch resistance (Amtec)	50	85	45	80	50	83
Xylene test	OK	OK	OK	OK	OK	OK
Acid test	12	25	11	23	10	22
Constant climate test	0/0	0/0	0/0	0/0	0/0	0/0

#### Test methods:

Indentation to DIN EN ISO 1520, value in millimetres

Amtec scratch resistance, stated as residual gloss after reflow in %

Residual gloss was measured in % (ratio of initial gloss of the clear coat surface to its gloss after wash scratching, gloss measurement in each case being performed at an angle of illumination of 20°). Wash-scratching was performed using an Amtec Kistler laboratory car wash system (c.f. Th. Klimmasch and Th. Engbert, Entwicklung einer einheitlichen Laborprüfmethode für die Beurteilung der Waschstraßenbeständigkeit von Automobil-Decklacken [development of a standard laboratory test method for evaluating resistance of automotive top coats to car wash systems], in DFO proceedings 32, pages 59 to 66, technology seminars, proceedings of the seminar on 29-30.4.97 in Cologne, published by Deutsche Forschungsgesellschaft für Oberflächenbehandlung e.V., Adersstraße 94, 40215 Düsseldorf).

#### Xylene test:

Brief description: A xylene-soaked filter paper is placed on the coating film for 10 minutes. Evaluation: OK = no visible change

Acid test:

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Brief description: at 65°C, 50 µl drops of 36% sulfuric acid are placed at 1 minute intervals for 30 minutes onto the coating film.

Evaluation: Destruction of the film after X minutes (0-30)

Constant climate test:

to DIN 50017, evaluation: degree of blistering m/g to DIN 53209

According to the invention, coatings were obtained which were tack-free in the shaded areas too (moisture curing only, thermally supported) and exhibited adequate hardness and elevated cross-linking, wherein the latter was in particular demonstrated by the xylene test.

**CLAIM(S)**

What is claimed is:

1. A process for multi-layer coating of substrates which comprises the steps of applying at least two coating layers and curing of the applied coatings with high energy radiation and moisture;

wherein at least one of the coating layers is formed from a coating composition comprising a binder system of resin solids wherein the resin has free-radically polymerizable olefinic double bonds and hydrolysable alkoxysilane groups, wherein the resin solids content of the coating composition has an equivalent weight of C=C double bonds of 200 - 2000 and has a silicon content of 1 - 10 wt-%, wherein the silicon is bound in alkoxysilane groups and wherein the step of curing of the at least one coating layer comprises irradiation with high energy radiation thereby polymerizing the C=C double bonds via free radical polymerization and exposure to moisture thereby forming siloxane bridges from the alkoxysilane groups.

2. A process according to claim 1, wherein the coating composition comprising a binder system of resin solids having free-radically polymerizable olefinic double bonds and hydrolysable alkoxysilane groups is applied onto a pigmented base coat layer and cured to form a clear coat layer.

3. A process according to claim 1, wherein the coating composition comprising a binder system of resin solids having free-radically polymerizable olefinic double bonds and hydrolysable alkoxysilane groups and being pigmented is applied as a one-layer top coat composition onto a substrate selected from the group consisting of a primer layer, a surfacer layer and a primer/surfacer layer and cured to form a pigmented one-layer top coat layer.

4. A process according to claim 1, wherein the coating composition with a binder system of resin solids having free-radically polymerizable olefinic double bonds and hydrolysable alkoxysilane groups is applied as a transparent sealing coat onto a multi-layer coating to form an outer transparent sealing layer.

5. A process according to one of the preceding claims, wherein the resin solids content of the coating composition comprises resins having free-radically polymerizable olefinic double bonds and hydrolysable alkoxy silane groups, an equivalent weight of C=C double bonds of 300 - 1500, and a silicon content of 1 - 7 wt-% wherein the silicon is bound in alkoxy silane groups.
6. A process according to one of the preceding claims, wherein the alkoxy silane groups comprise trialkoxy silane groups.
7. A process according to one of the preceding claims, wherein the binder system with free-radically polymerizable olefinic double bonds and with hydrolysable alkoxy silane groups additionally comprises hydroxyl groups.
8. A process according to one of the preceding claims, wherein the high energy radiation is UV radiation.
9. Use of a process according to one of the preceding claims for the multi-layer coating of vehicles and vehicle parts.
10. Use of the process according to claim 9 for the original multi-layer coating of vehicles and/or for repair of vehicle coatings.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 03/18604

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C09D175/16 C08J3/24 C09D201/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 02 090451 A (DOW GLOBAL TECHNOLOGIES) 14 November 2002 (2002-11-14) page 1, line 15 -page 11, line 16; claims 1-11; examples	1
A	WO 97 14737 A (DSM/JAPAN SYNTHETIC RUBBER) 24 April 1997 (1997-04-24) page 3, line 8 -page 10, line 37 page 16, line 31 - line 36; claim 1; examples UA-1,7 -/-	1



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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Date of the actual completion of the international search

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## INTERNATIONAL SEARCH REPORT

Int'l Application No  
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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International Application No

PCT/US 03/18604

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